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Cognitive Crescendos: A Review of Working Memory Training's Role in Advancing Musical Dictation Skills

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Abstract: This review investigates the crucial impact of working memory training on improving musical dictation abilities in music students. Ear training, a fundamental aspect of solfeggio courses in higher education, forms the basis for a wide array of musical competencies. The review presents a comprehensive synthesis of the definitions, theoretical frameworks, and empirical findings pertaining to working memory, with a particular focus on its influential role in music education. Central to this review is the multi-component model of working memory, which is examined in detail across its various developments and practical applications within cognitive psychology. The review thoroughly analyzes how working memory intersects with music dictation, emphasizing the critical role of memory in both understanding and performing music. It explores the physiological and cognitive aspects of musical memory, highlighting its importance in the development of auditory skills. Additionally, the article reviews various methodologies employed in working memory training, such as the n-back task, assessing their effectiveness in enhancing cognitive abilities relevant to music education. It delves into the concept of transfer effects in working memory training, differentiating between 'near transfer' and 'far transfer', and discusses their significance in the context of music education, particularly in tasks like rhythmic dictation. In summary, this review offers an in-depth exploration of the connection between working memory training and its practical implications in music dictation. It elucidates the transformative impact that cognitive training techniques can have in advancing music dictation skills, thereby making a substantial contribution to pedagogical strategies in the realm of music education.

Keywords: Working memory, music dictation, auditory skills development, music education pedagogy

Abstrak: Kajian semula ini menyiasat kesan penting latihan ingatan kerja terhadap meningkatkan kebolehan imlak muzik dalam pelajar muzik. Latihan telinga, aspek asas kursus solfeggio dalam pendidikan tinggi, membentuk asas untuk pelbagai kecekapan muzik. Kajian semula membentangkan sintesis komprehensif definisi, rangka kerja teori, dan penemuan empirikal yang berkaitan dengan ingatan kerja, dengan tumpuan khusus pada peranannya yang berpengaruh dalam pendidikan muzik. Pusat kajian ini ialah model berbilang komponen memori kerja, yang diperiksa secara terperinci merentasi pelbagai perkembangan dan aplikasi praktikalnya dalam psikologi kognitif. Kajian itu menganalisis secara menyeluruh bagaimana memori kerja bersilang dengan imlak muzik, menekankan peranan penting ingatan dalam memahami dan mempersembahkan muzik. Ia meneroka aspek fisiologi dan kognitif ingatan muzik, menonjolkan kepentingannya dalam pembangunan kemahiran pendengaran. Selain itu, artikel itu meninjau pelbagai metodologi yang digunakan dalam latihan ingatan bekerja, seperti tugas n-back, menilai keberkesanannya dalam meningkatkan kebolehan kognitif yang berkaitan dengan pendidikan muzik. Ia menyelidiki konsep kesan pemindahan dalam latihan ingatan kerja, membezakan antara 'pemindahan hampir' dan 'pemindahan jauh', dan membincangkan kepentingannya dalam konteks pendidikan muzik, terutamanya dalam tugas seperti imlak berirama. Ringkasnya, ulasan ini menawarkan penerokaan mendalam tentang kaitan antara latihan memori kerja dan implikasi praktikalnya dalam imlak muzik. Ia menjelaskan kesan transformatif yang boleh dimiliki oleh teknik latihan kognitif dalam memajukan kemahiran imlak muzik, dengan itu memberi sumbangan yang besar kepada strategi pedagogi dalam bidang pendidikan muzik.

Kata kunci: Ingatan kerja, imlak muzik, pembangunan kemahiran auditori, pedagogi pendidikan muzik

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1. Introduction

Ear training, a vital component of solfeggio courses, stands at the heart of musical education in higher learning institutions. This foundational discipline is imperative for music students in colleges and universities, serving as a mandatory core subject. Solfeggio's complexity and depth make it both challenging and crucial, acting as a pivotal element in nurturing students' musical acumen and fostering a diverse range of musical abilities, including vocal and instrumental prowess as well as dance skills (Junyuan, 2020).

The curriculum of solfeggio, an integral part of music education, encompasses auditory analysis, ear training, and sight-singing (Xuxi, 2020). Its primary objective is to cultivate a precise understanding of rhythm and pitch among music majors through exercises in auditory training, dictation, and sight-singing. This process not only strengthens musical memory and internal auditory skills but also lays the groundwork in essential theoretical concepts such as music theory, harmony, and musical forms. Furthermore, it sharpens practical abilities like rapid score recognition and precise vocalisation of musical scores.

These competencies establish a robust theoretical and practical base, enabling students to delve deeper into various musical disciplines. This comprehensive approach enhances their overall musical quality, deepens score interpretation, and fuels their imaginative capacities regarding sound effects. Consequently, this leads to an elevated comprehension and sensitivity towards music, ultimately enriching their musical aesthetics (Davis et al., 2016). Solfeggio training, therefore, is not only critical for aspiring professionals but also beneficial for amateur music enthusiasts in elevating their learning efficiency and aesthetic appreciation of music. Ear training, a crucial aspect of music education, involves the skill of recognising and transcribing music through attentive listening to familiar musical elements. This practice is central to honing musical writing and reading abilities. Starting from the onset of music education, ear training stands out as a key activity for developing vital mental processes in music, such as enhancing musical aptitude, memory, and cognitive skills. Music dictation, a primary component of ear training, specifically strengthens musical memory, inner hearing, and fosters the growth of imagination and imagery, culminating in improved dictation abilities.

Music dictation, the essence of ear training, entails the skill of accurately identifying and notating musical elements by listening attentively. This process requires perceiving each element sensorily, consciously learning it, and repeating it until the skill of precise recognition is attained. As Munir et al. (2012) highlight, music dictation exercises are indispensable from the early stages of music learning, proving to be the most effective method for developing mental faculties involved in musical performance, memory, and thought processes.

Memory, a vital human faculty, plays a fundamental role in learning, particularly in music. As Melby-Lervåg et al. (2016) notes, memory is the foundation of learning, and without it, acquiring knowledge, especially in the realm of music, would be impossible. Music, distinct from visual arts and literature, unfolds over time and relies heavily on memory for its comprehension and appreciation. Musical memory, a key area of study in music cognitive psychology, delves into how individuals perceive, learn, remember, and conceptualise music. This encompasses aspects like pitch, rhythm, timbre, melody, harmony, and auditory aesthetics. The significance of musical memory in processing music, as emphasised by Xu et al. (2023), cannot be overstated. It encompasses the physiological aspects of musical hearing, cognitive organisation of sound, tonal and musical memory, musical thinking, and aesthetics. Therefore, this review aims to address several research questions:

1) How is working memory defined in the literature?
2) What are the existing studies linking working memory to music dictation skills?

2. Literature Review

The concept of 'working memory' was first introduced by Miller, Galanter, and Pribram, marking its roots in the 1960s when theoretical studies began drawing parallels between the human brain and computers (Baddeley, 2003). This term gained further traction through Atkinson and Shiffrin's work in 1968, where they referred to 'short-term storage'—a concept we now recognise as working memory. Initially known by various terminologies such as 'short-term memory', 'operational memory', or 'temporary memory', it has evolved significantly over time (Fuster, 1997). Originally, short-term memory was understood as the capacity to hold information for brief durations, typically spanning a few seconds. However, contemporary theories have largely transitioned to the term 'working memory', a shift that underscores an increased scholarly focus on the dynamic aspects of information processing and manipulation within the realm of short-term cognitive functions.

Working memory is a critical cognitive system with a limited capacity, responsible for the transient preservation, processing, and manipulation of information (Baddeley, 2013). This cognitive mechanism is fundamental in supporting higher-order processes such as perception, reasoning, and problem-solving. Its significance extends to various aspects of an individual's capabilities, including fluid intelligence, attention control, reasoning skills, reading comprehension, mathematical abilities, academic performance, and everyday functioning (Sabol & Duell, 2024). Furthermore, working memory encompasses not just the storage aspect of short-term memory but also involves the active operation and processing of information, particularly in maintaining information during tasks that involve distraction or interference. It possesses the ability to repeatedly retrieve information from long-term, permanent memory (Lin & Gao, 2023).

Over the years, several theories have been developed to elucidate the concept and functionality of working memory. Among these, the model proposed by Baddeley and Hitch (2007), and later refined by Baddeley (2000), stands prominent. Their multi-component model of working memory delineates four components that process and integrate auditory and visual information: a central executive, a phonological loop, a visuospatial sketchpad, and an episodic buffer (referring to auditory sensory memory and working memory skills' association with achievement scores). Recent research has also revealed that individual working memory capacity can be enhanced through targeted training (Linder, 2009). Such advancements are classified under the umbrella of working memory's plasticity, which includes the potential adaptability of cognitive abilities and brain activities (Karbach & Schubert, 2013). The concept of working memory training has garnered considerable interest in academic circles, particularly in the last decade. Scholars in the field of music have focused on exploring the implications of working memory training in music education, seeking to infuse new perspectives from psychology into musical studies.

Working memory training, a technique aimed at enhancing cognitive functions, involves structured exercises or guided activities. This method effectively boosts working memory capabilities and general cognitive abilities. Typically, working memory training employs short-term interventions to enhance individuals' working memory and broader cognitive skills (Sabol & Duell, 2024). The training methodology usually involves an experimental design, incorporating pre- and post-test evaluations of both training and control groups. Participants in the experimental group undergo short-term training, followed by assessments to validate their performance improvements. Notably, working memory training not only enhances task-specific achievements, known as the training effect, but also exhibits a transfer effect, improving performance in other cognitive tasks (Sabol & Duell, 2024). This transfer effect is categorised into 'near transfer', which improves performance in untrained working memory tasks similar to the training tasks, and 'far transfer', which enhances abilities in related tasks like attention switching and reasoning (Gao et al., 2015).

Working memory training methods vary based on the tasks involved, including Cogmed working memory training, adaptive n-back training, adaptive active memory training, working memory span training, and complex span training. The n-back task, popularised by Thompson et al. (2013) for its significant impact on fluid intelligence, has become a widely utilised training task (Li et al., 2015). According to McClelland and Wanless (2012), working memory assessment encompasses four dimensions: goal maintenance, interference control, updating, and working memory capacity. Notably, the n-back task requires engagement in all these dimensions (Comfort & James McMahon, 2014). This relevance is mirrored in music education, specifically in sight singing and ear training for music majors, where tasks like rhythmic dictation necessitate these four cognitive dimensions, leading to the selection of the n-back task for this study.

The n-back working memory training task, or n-back paradigm, presents stimuli through visual or auditory means, requiring participants to identify if the current stimulus matches a stimulus presented 'n' steps earlier. The difficulty and working memory demand increase with higher 'n' values (Kilpatrick et al., 2011). For instance, in a 3-back task, subjects compare whether the current letter onscreen matches the one presented four positions back (Shipstead et al., 2012). Fig. 1 in the supplementary materials provides a visual representation of different N-Back tasks.

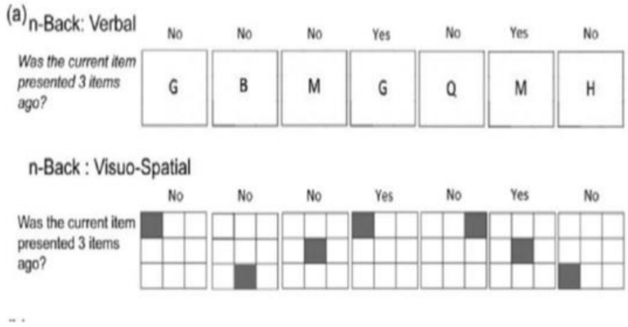

Fig. 1. Two types of N-Back tasks

The process of ear training for college students involves crucial elements like pitch rhythm control, horizontal melody and vertical harmonic analysis, acoustic feature analysis, and more (Alsalminy & Omrane, 2023). These components are fundamentally linked to music memory capabilities. Solfeggio and ear training equip students with various musical skills, enhancing their flexibility in practical music applications. Moreover, music memory plays a pivotal role in merging rational and emotional aspects, thereby strengthening musical hearing abilities. However, traditional Chinese solfeggio teaching methods face several challenges: 1) The teaching approach is outdated, heavily relying on repetitive piano practice for ear training; 2) Teaching materials are becoming obsolete, lacking contemporary pop music and folk music elements; and 3) A shortage of specialised solfeggio ear training instructors often leads to reliance on part-time teachers from other music disciplines (Junyuan, 2022). These shortcomings render traditional solfeggio training tedious, monotonous, and less effective for a diverse student body (Kilpatrick et al., 2011).

During ear training assessments, tasks like monophonic, interval, and chord listening require writing answers within seconds of hearing the material. Rhythm and melody listening, although allowing slightly more time, also demand quick comprehension through repeated short listening sessions (Ji, 2011). The process encompasses not only short-term memory skills (memorising pitch and rhythm) but also reasoning and judgment (applying music theory knowledge). This aligns closely with the operational mode of working memory. Consequently, this study aims to explore new ear training methodologies from the perspective of working memory in applied psychology. In essence, musical memory training and its application are critical in cultivating auditory skills in music (You, 2012). Therefore, focusing on ear training teaching research within the realm of working memory is both significant and meaningful.

3. Methodology

The methodological framework for this review begins with the careful development of a literature review strategy. This strategy serves as a crucial tool in identifying and selecting relevant keywords for database searches. The selection of keywords includes, but is not limited to, terms such as "memory," "musical memory," "working memory," "working memory training," "solfeggio ear training," "music dictation," "pitch dictation," "melody dictation," and "rhythm dictation."

An in-depth search is conducted primarily using the CNKI (China National Knowledge Infrastructure) and Google Scholar databases. The aim is to compile a comprehensive collection of scholarly materials. This collection encompasses peer-reviewed journal articles, monographs, government documents, conference proceedings, and doctoral theses. The selection of these sources is guided by criteria that emphasise empirical rigour and theoretical relevance to the study's objectives. This methodical approach is designed to ensure a comprehensive and critical engagement with the existing scholarly work, thereby facilitating a deep and nuanced understanding of the research topic.

4. Findings

The session reports the findings reviewed for each research question.

4.1 Research Question One

Memory, a fundamental function of the human brain, involves the storage, retention, reproduction, or recognition of experienced information, serving as the foundation for higher mental activities like thinking and imagination. Hailin et al. (2022) categorise memory based on the duration of information retention into sensory memory, short-term memory, and long-term memory. Tang and Chan (2021) describe sensory memory, also known as transient memory, as having a brief retention period, with information rapidly fading over time. Information garnering special attention or recognition transitions into short-term memory. Moeller (2021) defines short-term memory as the stage of processing, encoding, temporarily retaining, and having a limited capacity for stimulus information, acting as an intermediary from instantaneous to long-term memory. It serves the crucial function of temporarily storing information for its eventual transfer to long-term memory. As a unique form of short-term memory, working memory is a limited-capacity system crucial for storing and processing information. It is integral to various cognitive activities such as speech comprehension, learning, reasoning, and problem-solving, playing a significant role in advanced cognitive processes (Yang et al., 2020). The next section delves into the definition of working memory theory and its theoretical framework.

First of all, Fenesi et al. (2015) have integrated three dominant models of working memory (WM) in cognitive psychology: Baddeley’s multiple-component model (2012; 2003; 1986), Cowan’s embedded-processes model (2005; 1999), and Engle and Kane’s executive control model (2004). This integration aims to reconceptualise the working memory construct and re-evaluate its implications across various academic learning domains, including language comprehension and production, mathematics, and multimedia learning (Zhisheng, 2019). Next, Baddeley (2017) defines working memory as “a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning”. He first proposed the working memory model in 1974, subsequently refining and updating it in 2000 and 2011. The 2011 version, known as the Multicomponent Working Memory Model, incorporates an auditory loop, which includes musical stimuli. This model is illustrated in Fig. 2 as the Multicomponent Model.

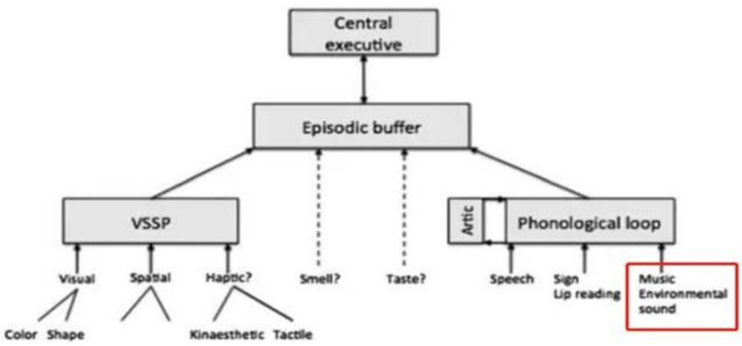

Fig. 2. Multicomponent model

Cowan (2014) succinctly defines working memory as “the limited amount of information a person can hold temporarily in an especially accessible form for use in the completion of almost any challenging cognitive task”. He initially introduced his working memory model in 1988, with subsequent elaborations in his 2005 monograph titled 'Working Memory Capacity'. This model, known as the Embedded-Processes Model, represents a significant contribution to our understanding of working memory. The intricacies of this model are visually depicted in Fig. 3.

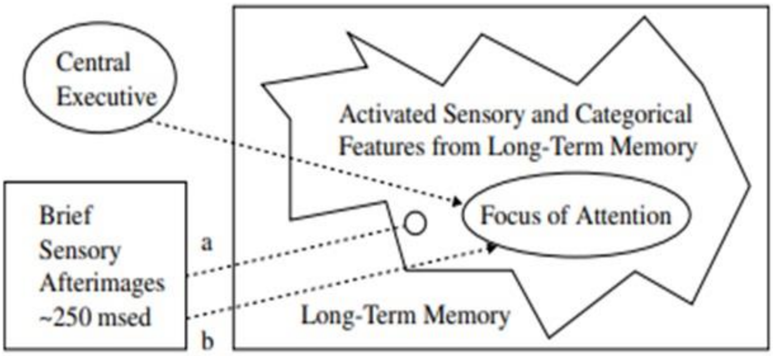

Fig. 3. Embedded-processes model

Engle and Kane (2004) conceptualise working memory as “a system comprising: (a) short-term ‘stores’ consisting of long-term memory (LTM) traces in various representational formats that are active above a threshold; (b) rehearsal processes and strategies for achieving and maintaining that activation; and (c) executive attention.” This definition encapsulates their working memory model, known as the Executive Control Model. The nuances of this model, emphasising the interplay between short-term storage, active rehearsal, and executive attention, are illustrated in Fig. 4.

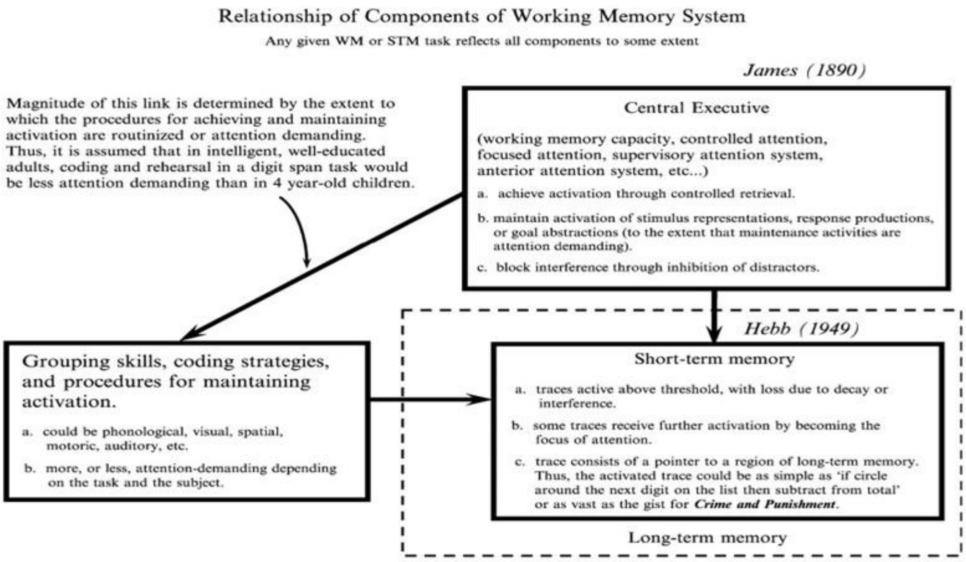

Fig. 4. Executive control model

The tripartite model of working memory, originally proposed by Baddeley and Hitch in 1974, is composed of three key subsystems: the central executive, the phonological loop, and the visuospatial sketchpad, as depicted in Fig. 5. The first subsystem, the central executive, functions as the core of the model. Its primary roles include coordinating the activities of other subsystems within working memory, controlling encoding and retrieval strategies, managing the attention system, and facilitating the retrieval of information from long-term memory. The second subsystem, the phonological loop, is tasked with the storage and management of auditory and verbal information. It enables the reactivation of diminishing speech representations, particularly through silent reading, and is capable of transforming written language into phonological codes. Lastly, the visuospatial sketchpad primarily handles the storage and processing of visual and spatial information, suggesting the presence of distinct visual and spatial components within this subsystem (Huajun, 2017).

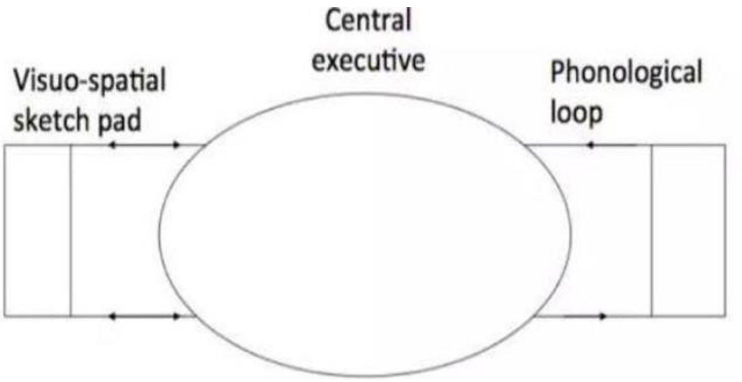

Fig. 5. Baddeley's three-component working memory model

In 1995, Berz introduced a theoretical model of music memory, building upon Baddeley's working memory framework. This model postulates that the central executive controller is a critical component of music working memory. It is envisioned to consist of two distinct loops: a language loop and a music loop. However, it's important to note that Berz did not provide experimental evidence to substantiate this theoretical model, as pointed out by Ricardo (2020). The conceptualization of Berz's model, with its integration of language and music components within the working memory structure, is illustrated in Fig. 6.

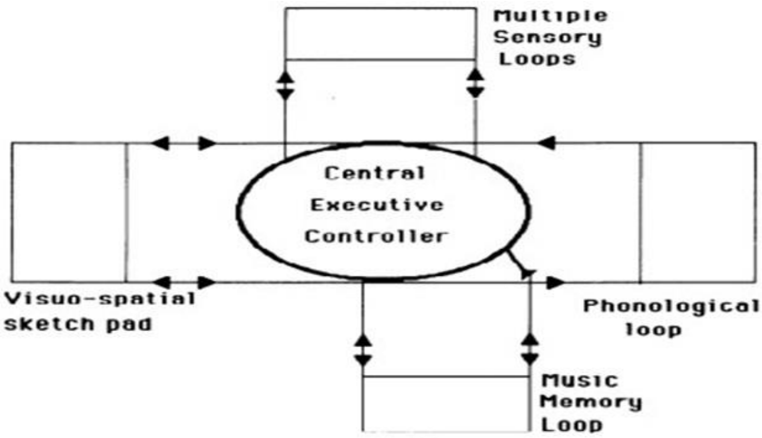

Fig. 6. Working memory theoretical model based on the working memory model by Baddeley (Berz, 1995)

In 2000, Baddeley expanded his original working memory model by introducing a new component, the episodic buffer, as depicted in Fig. 7. This addition not only enhanced the model but also established a connection between working memory and long-term memory. The episodic buffer serves as a limited-capacity storage area, governed by the central executive, alongside the phonological loop and the visuospatial sketchpad. It functions as a multidimensional code storage system, providing a platform for the temporary integration of information from the phonological loop, visuospatial sketchpad, and long-term memory. This integration process facilitates the combination of information from various sources into a coherent and unified scene through the central executive system. While the central executive is responsible for the integration of different types of information, the episodic buffer retains the outcomes of this integration, supporting further integration activities (Huajun, 2017). The updated model, inclusive of the episodic buffer, is illustrated in Fig. 7.

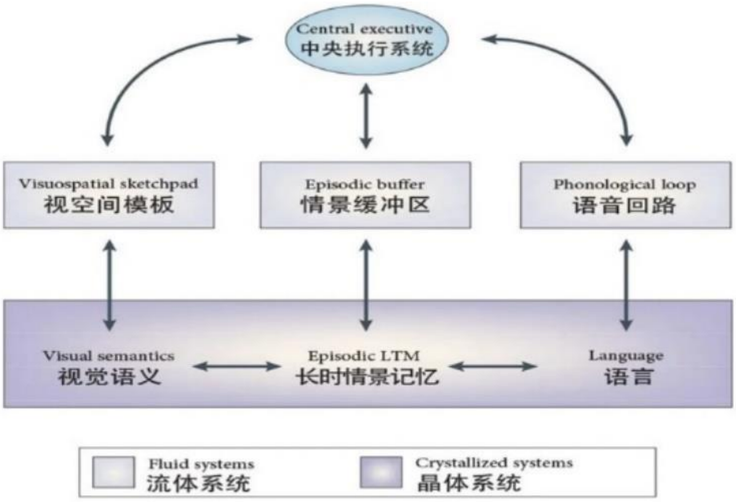

Fig. 7. Baddeley's four-component working memory model

In 2011, Baddeley further refined his working memory model, naming it the Multicomponent Model. This iteration underscores the diverse inputs from perception to working memory (Baddeley, 2021). The model proposes two main information streams, each feeding into either the visuospatial or the phonological subsystem. For the phonological loop, this encompasses auditory and linguistic information, whether presented through sound, print, sign language, or lip-reading. In the visuospatial sketchpad, the confluence of visual data (like color, shape, and location) merges with sensory information from touch, integrating inputs from various kinesthetic and tactile receptors. Both streams potentially converge in the episodic buffer, making them accessible to conscious awareness (Baddeley, 2021).

The phonological loop is specifically geared towards managing speech-based or verbal materials in working memory. Comprising a short-term store and an articulatory rehearsal mechanism, research has highlighted three key aspects of the phonological loop: 1) Storage within the loop is phonological, not visual (the phonological similarity effect); 2) Spoken material gains obligatory access to the storage component (the articulatory suppression effect); 3) Subvocal rehearsal likely occurs in real-time (the word length effect).

The visuospatial sketchpad is tasked with processing and storing visual and spatial information. Behavioral dual-task paradigms and neuroimaging studies suggest a partial separation between visual and spatial memory within this component. Lastly, the episodic buffer, introduced as a fourth component, acknowledges the interaction between long-term memory (LTM) and working memory (WM). This component serves as a bridge, facilitating the integration of information from LTM into WM processes (Schulze et al., 2011).

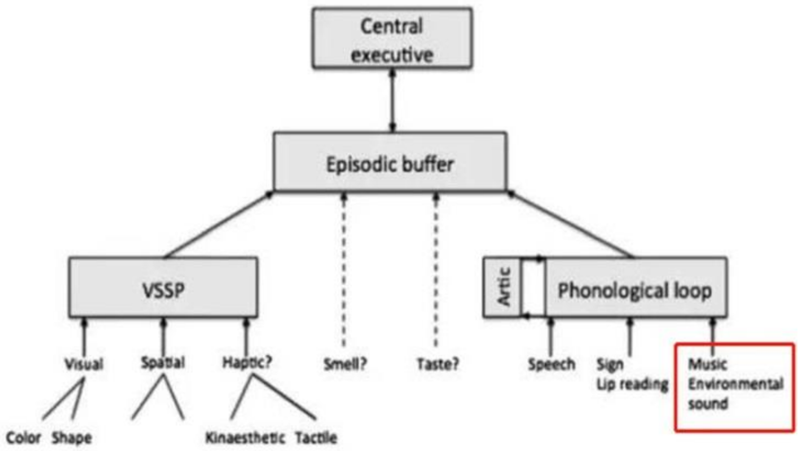

Fig. 8. Baddeley's multicomponent model

Baddeley's Multicomponent Model, despite its widespread acceptance and frequent use within the academic community (Bora, 2021), is not without its limitations. First and foremost, the model's specifications are not entirely clear-cut, leading to ambiguity regarding which cognitive processes fall outside the purview of working memory (WM). This lack of specificity hinders the model's predictive power and explanatory capacity, as the components of the model and their interrelationships are not thoroughly delineated.

Secondly, the simplicity of the model's components is a point of contention. While it provides a basic framework for understanding memory functions, it falls short in explaining complex everyday phenomena and does not delve deeply into the intricate workings of memory (Bora, 2021). This simplicity limits the model's applicability in addressing more profound questions about memory's operational mechanisms.

A third critical issue concerns the Central Executive (CE) component, which is arguably the least understood aspect of the model. The framework describing the organization and function of the CE lacks detail, which poses challenges in developing experimental tasks that specifically target aspects of executive function or engage the model's 'slave systems' without impacting the executive. Furthermore, the model's treatment of the CE’s role in rehearsal processes is underdeveloped. There is a need to reconsider and potentially redesign the CE component within the WM model to clarify whether rehearsal is a function exclusive to the slave systems, a function initiated and monitored by the CE, or solely a function of the CE itself (Bora, 2021).

4.2 Research Question Two

At the 2014 'Neuroscience Association International Conference', Heekyeong Park from the University of Texas at Arlington presented a notable study. This research revealed that musicians exhibit faster neural responses compared to non-musicians and outperform them in tasks related to working memory, including graphical and language tasks. Consequently, the study concluded that musicians possess superior capabilities in both working memory and long-term memory compared to non-musicians (Lin, 2015).

In a separate study, Bugos et al. (2007) explored the effects of individualized piano instruction on older adults aged 60 to 85 years. Their findings indicated that such instruction significantly enhanced attention and related cognitive abilities, which are integral components of working memory. Notably, these cognitive improvements were observed during the periods of active engagement in piano classes and practice. However, once the lessons and practice ceased, the cognitive benefits did not persist, suggesting that these enhancements were contingent on the continuous intervention of piano instruction (Bugos et al., 2007).

In 2015, Li explored the effects of music training on children's working memory in her master's thesis. Her study revealed that music training positively influences working memory. It involved three types of music training for a choir: reading spectrum training, listening training, and chorus training. By analyzing the working memory indices of children who had received music training against those who hadn’t, Li demonstrated that music training enhances the visuospatial sketchpad, the phonological loop, and the central executive systems, thereby boosting working memory capabilities (Li, 2015). Further, a study by Zhishen (2019) investigated the enduring effects of music training on executive function enhancement in preschool children. They found that music training fosters children's inhibitory control, working memory, and cognitive flexibility, with these benefits persisting over time.

Or-Kan et al (2020), after controlling for factors like age, socioeconomic status, and bilingualism, discovered a significant correlation between music training and improvements in both auditory and visual working memory. Similarly, Lim and Park (2019) utilized linear mixed-effects model analysis to establish that music training enhances working memory. This correlation is likely because music training involves the storage, manipulation, and integration of complex sequences of pitch and time, which are akin to tasks used in working memory assessments. Supporting this, Aloysius (2010) found a robust link between musical training and improved memory for dynamic information. Their results indicated that musical training positively correlates with sustained attention, visuomotor coordination, visual scanning, processing speed, spatial memory, and information processing ability. In another study, Cellini (2017) compared the performance of musicians and non-musicians on verbal working memory tasks and found that musicians consistently outperformed non-musicians. These findings underscore the connection between musical training and enhanced executive functions, including working memory (Henriksson et al., 2022).

In the field of neuroscience, research using functional magnetic resonance imaging (fMRI) has uncovered that similar neural networks are engaged during the rehearsal and storage of both tonal and verbal stimuli. Studies by Schulze et al. (2011); Koelsch et al. (2010); and Hickok et al. (2003) provide evidence for this overlap in brain activity. Conversely, Siddiqui et al. (2012) highlights that different brain regions process speech, auditory, and musical stimuli. Specifically, speech and words typically activate the left hemisphere, while melodies primarily stimulate the right hemisphere. Interestingly, rhythm seems to be processed without a clear bias towards either hemisphere.

Siddiqui et al. (2012) study delved into the impact of musical training and selective attention on the recall of paired melodic and imagery stimuli in a recognition memory test. The participants included both music and non-music majors. The findings revealed a notable difference between the two groups. Music majors, whether distracted or selectively attentive to musical conditions, consistently outperformed non-music majors. However, in tasks requiring selective attention to pictures, non-music majors surpassed music majors. These results indicate a significant link between musical training, particularly regarding tone stimuli, and verbal working memory.

5. Discussions

The multi-component model of working memory, as expounded by Linder (2009) and Karbach and Schubert (2013), elucidates the intricate interactions among components like the central executive, phonological loop, and visuospatial sketchpad. This model underscores the adaptability and plasticity of working memory, which can be honed through specialized training. This aspect is crucial in music education, where exercises designed to enhance working memory and overall cognitive abilities bridge psychological principles with musical training.

Research, including studies by Cellini (2017) and Aloysius (2010), has shown that musical training correlates positively with an array of cognitive skills, such as sustained attention, visuomotor coordination, and spatial memory. These findings suggest that musical training bolsters not only specific working memory components but also a broader spectrum of executive functions. Functional magnetic resonance imaging (fMRI) studies provide insight into the neural underpinnings of these processes, revealing substantial overlap in brain activity during the rehearsal of tonal and verbal stimuli.

Investigations into the long-term impact of music training on cognitive development in children, as conducted by Or-Kan et al. (2020) and Hambrick & Engle (2003), demonstrate lasting improvements in executive functions like inhibitory control and working memory. These enduring effects highlight the profound influence of early musical training on cognitive growth. Furthermore, studies by Lara & Saracostti (2019) and Bugos et al. (2007) emphasize the necessity of continuous musical training for maintaining cognitive gains. Such training actively enhances attention-related cognitive abilities, which are integral to working memory. However, these cognitive benefits tend to wane without ongoing musical practice, underlining the importance of sustained musical engagement. Additionally, Siddiqui et al. (2012) sheds light on how musical training specifically enhances verbal working memory and processes related to tone stimuli, indicating a specialized impact on various cognitive functions.

Overall, this body of research collectively provides a holistic understanding of the intertwining of musical training and working memory, illustrating their significant influence on cognitive abilities across diverse age groups and settings.

Recent research in the field of working memory training and its impact on musical skills offers a nuanced perspective, highlighting varied benefits across different age groups. Mussoi (2021) challenges the longstanding belief that lifelong music training substantially enhances speech recognition and working memory in older adults, suggesting a more intricate relationship than previously understood. In contrast, Lippolis et al. (2022) found that musical instrument training during preadolescence correlates with improved audiovisual working memory and fluid intelligence, emphasizing the significance of musical training in cognitive development during key transitional life stages.

Bruder et al. (2022) contribute to this discourse by demonstrating the positive effects of formal music training on cognitive abilities, specifically noting enhanced working memory related to speech intelligibility in challenging acoustic environments. This finding has practical implications for music education, especially in high-stakes professional settings. Complementing this, Galloway and Strong (2021) report that older adult musicians outperform non-musicians in tasks involving working and verbal memory, suggesting that musical training can significantly bolster these cognitive functions in later life.

The role of early musical training in developing executive functions is further illuminated by Chen et al. (2022). Their research indicates that such training enhances attention inhibition and working memory in children, pointing to early childhood as a sensitive period for impactful musical training on executive function development. Additionally, Paquet et al. (2022) demonstrate that musical practice affects neural mechanisms underpinning auditory retrieval in children, extending the benefits of musical training from basic auditory skills to more complex auditory memory processes. Collectively, these studies highlight the considerable influence of musical training on working memory and associated cognitive functions, revealing observable benefits at various stages of life. The diversity of outcomes across these studies suggests a complex interaction between factors such as age, type of musical training, and the specific cognitive abilities being evaluated.

In this review, the intricate relationship between working memory training and its influence on musical education, particularly in the realms of ear training and music dictation skills at the tertiary level, is thoroughly examined. The research delves into the critical role of working memory in music education, confronting both the challenges and the potential for integrating working memory enhancement to improve students' musical dictation competencies. Among the challenges, the study highlights the outdated solfeggio teaching methodologies that rely excessively on monotonous piano drills and lack modern musical elements. Additionally, there is a noticeable scarcity of specialised solfeggio ear training educators, often leading to the reliance on part-time instructors from other disciplines. This is compounded by the issue of curricular stagnation, as teaching materials fail to incorporate contemporary music genres, thus diminishing engagement and relevance for a varied student body. On the potential side, the research points to the significant benefits of working memory training in elevating cognitive abilities such as attention control, reasoning skills, and overall academic performance, which are crucial in music education. Specifically, integrating working memory training into ear training courses is posited to substantially enhance students' abilities in music dictation, auditory processing, and musical memory. The broader implications of working memory training methodologies in music education could enrich students' overall musical comprehension and deepen their score interpretation skills. The conclusion of the study underscores the substantial opportunities presented by the integration of working memory training into music education, emphasising the need for innovative updates to traditional teaching methodologies to advance students' musical dictation skills.

The review presents a compelling case for a paradigm shift in music education, advocating for the integration of working memory training. This innovative approach proposes enhancing cognitive capabilities alongside musical skills, potentially leading to a more comprehensive music education framework. In this model, students would not only grasp musical concepts but also strengthen cognitive functions such as attention control and reasoning, skills that are advantageous across various life aspects. The prospect of improving music dictation skills through working memory training is particularly transformative. It could significantly elevate musical memory and inner hearing capacities, paving the way for more intricate and refined musical interpretations. Such advancements might foster a deeper appreciation and comprehension of music, both within academic realms and in wider musical communities.

Furthermore, updating teaching materials to include contemporary music genres, as suggested by the article, could make music education more relatable and engaging for a diverse student population. This modern relevance is essential for sustaining student interest and motivation, which is often a hurdle in conventional music education frameworks. The review also underscores a notable deficiency in specialised instructors, highlighting the need for a multidisciplinary approach to music education. This could involve collaboration between educators from various fields to craft curricula that blend musical and cognitive training, potentially leading to groundbreaking teaching methodologies and resources that benefit both students and educators.

However, this shift towards integrating working memory training in music education is not without its challenges. Revamping curricula, preparing instructors to adopt these new teaching techniques, and investing in research and development for effective working memory training programs tailored to music education demands substantial time, resources, and a shift away from traditional pedagogical practices. In summary, incorporating working memory training into music education offers a promising path to reinvigorate and enhance the way music is taught and learned. It promises a more engaging, effective, and holistic educational experience. Yet, realising this potential is contingent upon overcoming substantial obstacles, including the modernisation of teaching methodologies, the creation of innovative curricula, and the professional development of educators.

6. Conclusion

In summary, the review presents a comprehensive view on the integration of working memory training in music education. It underscores the potential benefits such as enhanced cognitive functions and improved musical skills, alongside the challenges of outdated teaching methods and resource limitations. The implications of this approach are significant, suggesting a transformative shift in music education towards a more holistic, cognitive-based curriculum. However, to realise these benefits, substantial changes in teaching methodologies and resource allocation are necessary. This transition, while challenging, could lead to a more engaging and effective music education system that not only teaches musical concepts but also develops critical cognitive skills.

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